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ABSTRACT

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Individual Differences and the use of Analogies in Technical Text

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Abstract

The effects of verbal analogies and quantitative and verbal aptitudes on comprehension and memory of a technical text were studied. In a cued recall test, the presence of an analogy decreased the performance of high quantitative aptitude university students (measured by SAT scores), and tended to increase the performance of low quantitative aptitude students. In a three-way interaction of analogy effects on free recall of factors affecting conductivity, the analogy increased the performance of the high verbal, low quantitative aptitude group, and had no effect on the high verbal, high quantitative group or either low verbal aptitude group. A difference in processing strategy is proposed as the cause of these effects.

Individual Differences and the Use of Analogies in Technical Text

One of the most often used methods of explanation is presenting an analogy. There are many times when an analogy brings an unclear concept or relationships into clearer focus. At other times there is no meaning or comprehension at all, and an analogy can click on the light of understanding. Since analogies are so common, and they intuitively seem to be so powerful, study of when and how analogies work and do not work is very important and has many practical applications. This knowledge can help us teach better and learn more efficiently.

Some studies have found beneficial effects of analogies on a variety of learning outcomes including verbal information (Mayer & Bromage, Note 1; Reynolds, Schwartz, Esposito, Note 2; Rigney & Lutz, 1976), problem-solving (Reed, Ernst, & Baneiji, 1974), and transfer (Royer & Cable, 1976). Other studies, however, have failed to find a beneficial effect for analogies (Bielinski, 1974; Davison, 1976; Devine-Hawkins, 1974) or have obtained mixed results (Tepaske, Pearson, & Hyser, Note 3). A possible explanation for the mixed findings is that analogies do not help all types of learners. The major purpose of the present study was to explore the possibility of aptitude by treatment interactions in analogy effectiveness.

Towards this end college students read and recalled a passage on electrical conductivity. One-half read a form of the passage that contained analogies comparing the factors affecting conductivity to people at a party and one-half read a no analogy form that was equated for content

with the analogy form. The results were analyzed using verbal and quantitative SAT scores as moderator variables.

Method

Subjects

Subjects were 114 university juniors and seniors taking an educational pscyhology course. Verbal and Quantitative SAT scores were obtained from the university registrar. None of the students were physics majors but 23 had taken a college physics course.

Design

Subjects were randomly assigned to one of the two passage forms. Verbal and Quantitative SAT scores were used as blocking variables for the analysis. The sample was split into a high and a low group at the median of each measure. The median verbal score was 455 and the median quantitative score was 475.

The analysis was done using a 2 x 2 x 2 ANOVA with the variables being Verbal SAT, Quantitative SAT, and Passage Form.

Materials

The passage presented to the subjects concerned electrical conductivity and the factors that influence conductivity.[1] These factors were crystal structure, temperature, and magnetism. There were two forms of the passage, one with and one without analogies. These forms were 546 and 528 words long, respectively. The analogies compared electrons and crystals in the structure of the conductor to people at a party. For example, in describing the effect of temperature on the flow of electricity the analogy form of the passage said:

> An increase in temperature causes the cyrstals in the conductor to vibrate faster. Think again of the party. It is harder to walk across the room when people are dancing than when they are just standing and talking. The increased vibration of the crystals tends to increase electron-crystal collisions, which reduces the electron flow.[2]

Analogies were presented at four places in the passage. Specifically, an analogy was used to illustrate each of the following ideas: (1) current flow, (2) the effect of structure on conductivity, (3) the effect of temperature on conductivity, and (4) the effect of magnetism on conductivity.

The sentences corresponding to the analogy sentences in the no analogy form made the same point but without using an analogy. For example, the no analogy passage segment corresponding to the above underlined passage segment said:

> The more active the crystals, the more they will decrease the electron's motion through the conductor.

The passage forms were equivalent except for these four analogy presentations.

Procedure

The study was administered in groups that varied in size from 10 to 35 subjects. Each subject was given a booklet containing one form of the passage, a blank page for the free recall task, and the cued recall test. They were instructed to read carefully and try to remember as much of the passage as possible, but were not told about the tests. Subjects worked

at their own rate, but could not look forward or backward in the booklet at any time. They recorded their reading time, and then followed instructions printed in the booklet for the free recall test and the cued recall test. The instructions for the free recall test were to recall as much of the passage as possible. For the cued recall test the subjects were instructed to fill in the blanks with the exact wording of the passage if possible.

Dependent Measures

There were two dependent measures: (1) free recall of the factors affecting conductivity and (2) cued recall. The free recall score reflected recall of material presented in the analogy while the cued recall score reflected recall of the material from the rest of the passage. All scoring was done without knowledge of the passage form.

In the free recall test, subjects were asked to write down all they could remember from the passage. This was then scored for statements of the three factors affecting conductivity. These factors had been presented as analogies in the analogy form or stated abstractly in the no analogy form. Interscorer reliability for the free recall measure was .92.

The cued recall test consisted of 18 sentences from the passage with one to three words or phrases deleted to be filled in by the subjects. The deleted words were important concepts, ideas, or relationships from the passage. A substance scoring procedure was used since our interest was in comprehension rather than verbatim recall. Therefore specified synonyms and subordinate and superordinate categories were counted as being correct.

Results

Verbal SAT, Quantitative SAT, number of physics courses taken, and passage reading time were analyzed for differences between subjects reading the different passage forms, and the two groups were equivalent on all four measures.

Free Recall

The free recall test had a maximum score of three and the mean score was .63. The 2 x 2 x 2 ANOVA[3] revealed a significant main effect of Verbal SAT, $F(1,106) = 7.18$, $MS_e = .9029$, $p < .01$. The high verbal group had a mean of .91 while the low verbal group had a mean of .34.

A quantitative SAT x Verbal SAT x Passage Form interaction was also obtained, $F(1,106) = 3.87$, although not quite at conventional levels of significance, ($p = .052$). The means for this interaction are shown in Table 1. Comparisons between the analogy and no analogy forms for each of the four ability groups revealed that the difference between forms for the high verbal, low quantitative subjects was significant, $t(15) = 2.02$, $p < .06$, with the direction favoring the analogy form ($M_a = 1.29$; $M_{no\ a} = .40$). No other pairwise differences were significant.

Cued Recall

The maximum score for the cued recall test was 33 and the mean score was 17.90. The ANOVA revealed main effects for Verbal SAT, $F(1,106) = 13.56$, $MS_e = 38.60$, $p < .01$, and for Passage Form, $F(1,106) = 5.28$, $p < .05$. For the high verbal group the mean was 20.71 while for the low the mean was 15.09. The no analogy form produced a mean of 18.67 correct and the analogy form produced a mean of 17.06.

A significant Quantitative SAT x Passage Form interaction was also obtained, $F(1,106) = 10.83$, $p < .01$. The means for this interaction are shown in Table 2. Comparisons showed that for high quantitative subjects, reading the no analogy form resulted in better performance than did reading the analogy form, $t(53) = 3.14$, $p < .01$, while for the low quantitative subjects there was no significant difference between passage forms but there was a trend for information from the analogy form to be better recalled than that from the no analogy form.

Discussion

The results indiciate that for recall of the main points of the passage (i.e. the three factors affecting conductivity), the analogy form was beneficial for subjects with high verbal but low quantitative aptitude scores. However, for overall recall, the no analogy passage form was more effective than the analogy form and this was especially true among subjects with high quantitative aptitude scores. The finding of an interferring effect for an analogy is unusual in the literature so it is important to consider why this effect was obtained.

The effects we obtained can be explained by postulating reading strategy differences between high and low aptitude students. It seems reasonable to differentiate two strategies that may be employed in the reading of technical texts. These differ in what part of the text stimulates the most elaborative processing. A strategy that focuses on the concepts in the passage and develops meaning by relating these new concepts to prior information will be referred to as the "external elaboration" strategy. A strategy that focuses on relationships among

concepts and develops meaning by creating rich interrelationships will be referred to as the "internal elaboration" strategy.

These strategies are represented in the flow diagrams in Figure 1. These are not meant to be complete flow diagrams. They merely suggest the major differences between the two strategies. We do not believe that these strategies are "all or none" packages, but rather that segments of the strategies have varying strengths. Therefore, segments of each strategy may appear in any given individual's behavior.

As can be seen from the figure, the strategies have many conditions and actions in common. Both strategies involve encoding initial sentences until the major topics have been identified (points 1 and 2 in Figure 1), and both involve encoding additional sentences and the relationships among topics (points 3 and 4).

However, there are two differences between the strategies. First, the internal elaboration strategy has a step that occurs after the establishment of the relationships among topics which is not found in the external elaboration strategy. In this step (labeled Q) the reader's goal is to establish further relationships among topics. To the extent that this goal is achieved through a content-free logical analysis, the new relationships will not create connections with prior knowledge. Thus what evolves are elaborations that are internal to the new memory structure. The second difference is that the external elaboration strategy has a step (labeled V) early in the strategy which is lacking in the internal elaboration strategy. The goal of this step is to establish meaning for the passage topics by connecting them to prior knowledge.

The result is that the representation of passage information has rich elaborations to prior information.

The people who employ the internal elaboration strategy seem to have a set of procedures which enables them to look at variables and relationships between variables regardless of the context. Therefore, when they read the information about electrons, temperature, crystals, and so forth, the relationships of these are generally comprehended. By contrast, when the people who employ the external elaboration strategy read the information about electrons, temperature, crystals, and so forth, no meaning can be given to these excerpts through association with prior knowledge. These people are not able to completely comprehend the relationships between unfamiliar and therefore many times meaningless concepts.

An explanation of the present results follows from these models if it is assumed that people of high quantitative aptitude have a stronger tendency to examine the internal logic of the relationships in the new information than do people with low quantitative aptitude, and, by contrast, that people of high verbal aptitude have a stronger tendency to search for the meaning of unfamiliar passage topics. Since success on the quantitative SAT depends in part on understanding relationships among meaningless variables and since success on the verbal SAT depends in part upon guessing the meaning of unfamiliar terms, this assumption seems to be warranted. People who are high in both aptitudes are likely to be quite flexible and use either strategy.

A high quantitative person, then, would read the experimental passage in the following manner. He or she would first encode the

early sentences until topic labels had been identified. Then he or she would read further sentences with the goal of finding relationships among the previously identified topic labels. If an analogy is encountered this delays the achievement of this purpose (step I in Figure 1). The reader must stop and figure out that people represent electrons, dancing represents fast moving electrons, etc. Figuring out the correspondences between the initial topic labels and the analogy labels involves much of working memory so other information that was in working memory may be lost. Once the analogy correspondences are made the reader may proceed with the goal of finding relationships among topic labels and the later goal of inferring other relationships that are logically consistent with the explicitly stated relationships. If an analogy is not encountered, the high quantitative reader can proceed to meet all of his or her goals without disruption and therefore without loss of information from short term memory. Thus, for overall recall of the passage, a person following the internal elaboration strategy is better off without analogies.

In contrast, a low quantitative, high verbal person, after identifying the topic labels would search for meaning for these labels in his or her related prior knowledge. The analogies in the present passage are facilitative of this goal. If the meaning of crystal structure is somewhat vague, that of people grouped at a party is extremely rich. Once the meaning is established it is easy to comprehend the relationships and encode them. There is no disruption, as there is in the internal elaboration strategy, because the correspondences between initial labels and analogy labels have already been made as part of the first goal

of establishing meaning for the topics. The elaboration around the analogy provides a strong retrieval cue for analogy-related information and hence readers using the external elaboration strategy show better recall of this information when the analogy is provided than when it is not provided.

The different effects obtained for the two dependent measures--general cued recall and free recall of main ideas--is consistent with the above interpretation. That is, the analogy should have a general disruptive effect on recall for high quantitative people. However, the beneficial effect of the analogy for low quantitative, high verbal people should be fairly specific to the recall of the ideas presented in the analogy.

There are two alternative explanations of the findings that need to be considered. One is that high quantitative aptitude subjects have greater prior knowledge of physics because they are more likely to elect physics courses. This prior knowledge then interferes with the use of analogies. This explanation is not viable for the data. Although number of college physics courses was significantly correlated with free recall ($r = .25$, $p < .01$) and cued recall ($r = .39$, $p < .001$), analyses of covariance using number of college physics courses as the covariate yielded no different results than the reported analyses of variance; F values and probabilities were only minimally changed.

A second alternative is that high verbal subjects are better at verbal analogical reasoning. The problem with this interpretation, is that it is not really an explanation. That is, it does little to elucidate how high verbal subjects' skill at analogical reasoning helps him or

her in passage comprehension and memory representation. Also it is difficult to understand, using this interpretation, why the different passage forms don't affect the two dependent measures in the same way. Specifically, the high verbal, low quantitative subjects should have benefited from reading the analogy form. This result, however, was not obtained.

The explanation of strategy differences is consistent with the data and with current cognitive theory. However it is also post-hoc and therefore further research is needed. In particular, the SAT score is a global variable that stands in for more specific individual differences. The differences are (a) the tendency to examine and elaborate on the internal logic of new information, and (b) the tendency to search for meaning for new concepts. It would be useful in future research in this area to develop ways of measuirng these differences more directly. Another implication of the present analysis is that the effectiveness of analogies depends not only on individual differences but on the interaction of individual differences with the role that the analogy was to establish meaning and thereby facilitate retrieval. In some other passage an analogy might play the role of increasing the internal cohesion of the passage and under such conditions it might well be the high quantitative rather than the high verbal person who benefits from the analogy.

In summary the present study found interactive effects on recall among quantitative and verbal aptitude and the provision of analogy. The interpretation suggested by these results is that individual strategies

and the role of the analogy in given text interact to determine the analogy's effectiveness.

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Footnotes

[1]We are grateful to Dr. James M. Royer for providing the passage which formed the basis for our passage.

[2]The analogy was not underlined in the presentation to subjects, but is underliend here for clarity.

[3]Hsu and Feldt (1969) showed ANOVA can be used with a three point scale with no substantial loss of power or increase of error.

Table 1

Free Recall of Factors Affecting Conductivity

(Number of Main Ideas Recalled Out of 3)

Quantitative SAT	Passage Form	High Verbal SAT			Low Verbal SAT		
		M	SD	n	M	SD	n
High	No Analogy	1.11	1.24	19	.12	.35	8
High	Analogy	.86	1.08	22	.66	1.21	6
Low	No Analogy	.40	.70	10	.31	.68	26
Low	Analogy	1.29*	1.11	7	.38	.89	16

* differ significantly, $p < .06$

Table 2

Cued Recall of Passage Material

(Number of Blanks Correctly Filled Out of 33)

Quantitative SAT	Passage Form	M	SD	n
High	No Analogy	23.30	6.37	27
High	Analogy	17.50 *	7.29	28
Low	No Analogy	15.19	6.59	36
Low	Analogy	16.52	5.45	23

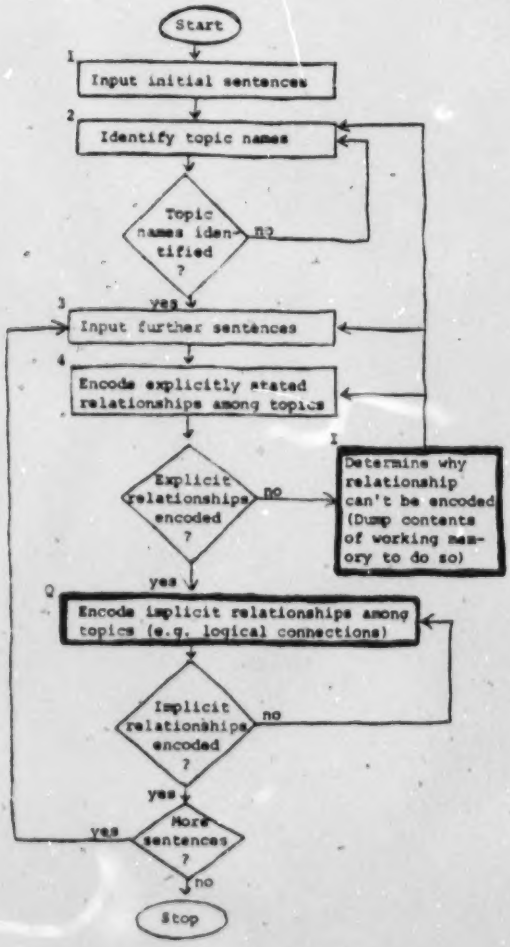
* differ significantly, $p < .01$

Figure Caption

Figure 1. Flow diagrams of strategies used in the elaboration of technical text.

INTERNAL ELABORATION STRATEGY

(High quantitative subjects)



EXTERNAL ELABORATION STRATEGY

(High verbal subjects)